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Effects of Enrichment on the Thiamine, Riboflavin and Niacin of Corn Meal and Grits as Prepared for Eating

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DIGEST

This bulletin deals with the increase in the vitamin value of corn meal and grits dishes due to the enrichment of the cereals in the raw stage.

Non-enriched degermed corn meal and grits were obtained from Texas mills. Part of each batch was enriched by adding a commercial mixture of vitamins and minerals such as millers use. Sour milk corn bread, boiled grits and fried grits were prepared from both the enriched and the non-enriched cereals. Only enriched corn meal was used for sweet milk corn bread, spoonbread, pone and mush. The preparation of each dish according to a standardized recipe was as nearly as possible like Texas home procedure. Each preparation was analyzed to find out how much of each vitamin was left in the cooked product.

Approximately the same amount of riboflavin and niacin was in each preparation after cooking as before, whether or not enriched cereal was used. But of thiamine, only mush and grits boiled 30 minutes had as much as in the raw cereals. Spoonbread and pone had 90 percent as much thiamine after cooking as before. From 84 to 89 percent of the thiamine was left in corn bread made with the standard amount of soda (½ teaspoon to 1½ cups sour milk) and of baking powder (1½ teaspoons to 2 cups meal). When too much soda and baking powder were used, only 7 percent of the thiamine was left in the bread.

Mush and grits after 4 to 7 hours further cooking in a double boiler had only two-thirds to three-fourths as much thiamine as when boiled 30 minutes. Frying of boiled grits destroyed a small amount of thiamine.

Enriched corn bread furnishes 2 times as much thiamine, 1½ times as much riboflavin and 3 times as much niacin as non-enriched. Of the recommended allowance for a man, one 5-ounce serving of enriched corn bread supplies one-fifth of the thiamine and riboflavin, and one-sixth of the niacin. Pone also is excellent for thiamine and niacin; spoonbread, for riboflavin. Spoonbread and short cooked mush are good sources of thiamine and niacin since in one serving there is about one-tenth of the recommended allowance. Enrichment changes cooked grits from a poor to a fair source of the three B vitamins.

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Effect of Enrichment on the Thiamine, Riboflavin and Niacin of Corn Meal and Grits as Prepared for Eating

Kathreen Thomas, June K. Pace and Jessie Whitacre*

CORN MEAL AND GRITS are used exclusively in the South. These cereals may have an important part in the betterment of Southern diets if their quality is improved by enrichment.

In Texas, especially among rural families, corn meal is an important food item, as shown by a survey of the food supply of 387 white and negro families (15). The ratio of meal to flour was 1 to 1.5 for white families and 1 to 1.6 for negro. The corn meal consumption of these families averaged 1.6 pounds per person weekly. This is equivalent to 370 calories per day, or about 12 to 15 percent of the daily energy need of physically active adults.

Corn is among the cereals low in niacin, the pellagra-preventing vitamin. It is very low in tryptophane, the amino acid which can compensate for a deficiency of niacin (8). Pellagra, still among health problems in Texas, is widely distributed over the State, as shown by the records of the Texas State Department of Health. Although, over recent years, there has been a rapid, continuous decline in the reported incidence of this disease, 395 cases and 42 deaths were reported for the year ending December 31, 1950. The situation is probably not as good as the records indicate because of incomplete reporting by doctors over the State.

With pellagra, as with other kinds of malnutrition, multiple vitamin deficiencies and sometimes mineral and good quality protein deficiencies are known to exist. The enrichment of corn meal and grits by the addition of thiamine, riboflavin, niacin and iron to both cereals, and of calcium to corn meal, makes them excellent foods to combat pellagra and to promote general good health.

The greatest possible benefit from enrichment can be realized only if corn meal and grits are prepared so as to retain in palatable and attractive form as much as possible of both

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natural and added nutrients. The best methods to achieve that end were not known prior to a study of vitamin retention by the research committee of the Texas State Nutrition Council.[1] This laboratory work was a unit within the cooperative undertaking of several agencies concerned with the nutrition of Texans, and was directed toward having only enriched corn meal and grits available in the State. Progress reports of the cooperative work have been published (16, 17, 18, 19) and a complete account is expected later.

This bulletin deals with the data accumulated only at the Texas Station, where the authors were participants in the cooperative study.

PROCEDURE

General Plan

The ways in which Texans use corn meal and grits were determined in a special survey made by the community nutrition section of the Texas Dietetic Association. The most popular dishes were chosen for laboratory use. For each dish chosen, a recipe was standardized. The products made by the standardized recipes, with the cereal enriched in the laboratory or with the corresponding non-enriched cereal, were analyzed for thiamine, riboflavin and niacin. Retention of each vitamin in each preparation was calculated. An estimation was then made of the value of the food preparation as a source of each vitamin.

Standardization of Recipes

Standardized recipes were formulated for corn bread, corn pone, spoonbread, mush, fried mush, boiled grits and fried grits. The proportion of ingredients and the manipulation was as nearly like home procedure as laboratory controls would permit. As a condition for adopting each recipe, the product it yielded was given a high rating on eating quality by a number of judges. The ingredients in each standardized recipe are shown in Table 1.

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[1]This committee is composed of one nutritionist in each of the five Texas institutions in which food and nutrition research is done. During the time of this study the committee members were: Mina W. Lamb, Texas Technological College; Laura McLaughlin, Texas State College for Women; Florence I. Scoular, North Texas State College; Jet C. Winters, University of Texas; and Jessie Whitacre, Texas Agricultural Experiment Station.

Standardized "Texas corn bread" (17) was based on 85 recipes collected from homes widely scattered over the State, one-fourth of them rural. These recipes were analyzed to show the amount of flour used to 1 cup of meal, of soda to 1 cup of sour milk, and the amount each of milk, egg, fat, sugar, salt and baking powder to 1 cup of meal plus flour. Such wide variations were found in the proportion of ingredients that it was necessary to standardize more than one recipe. The standardized recipes employ the modal proportions of ingredients, except that leavening is below modal. Two standardized recipes were used in this study, one calling for sweet milk, the other for sour milk.

The recipe for spoonbread was standardized on the basis of an analysis of the proportions of ingredients in 17 recipes obtained from published sources. The directions in cook books and on cereal packages were used as guides to determine the exact procedure for making pone and mush and for cooking grits.

To determine the effect of pH on retention of vitamins in corn bread, the sour milk recipe was modified in respect to leavening. One modification used very low leavening—1.5 g of baking powder and 1 g of soda; the other, very high leavening—18 g of baking powder and 5.7 g of soda. The amounts

Table 1. Ingredients used in standardized recipes for corn meal and grits preparations

Ingredients	Weight of ingredients in each preparation							
	Corn bread, sour milk	Corn bread, sweet milk	Spoon-bread	Pone	Mush, boiled 30 min.	Mush, long cooked[1]	Grits[2] boiled 30 min.	Grits, long cooked[1]
	Grams	Grams	Grams	Grams	Grams	Grams	Grams	Grams
Meal	250	250	125	125	125	125		
Grits							110	110
Milk, sour	375							
Milk, sweet		375	500					
Water				195	775[3]	840[3]	775[3]	840[3]
Egg	48	48	96					
Salt	6	6	6	6	6	6	6	6
Baking powder	4.5	4.5	2.25					
Soda	1.9							
Fat	24	24	12				6 to fry	6 to fry

[1]Long cooked means cooking in double boiler: mush 4½ and 5½ hours, grits 5 and 7 hours, after boiling for 30 minutes.

[2]The grits were not washed before cooking.

[3]The measured water was weighed each time and varied not over 5 grams.

of leavening in the modified recipes are within the range of the proportions used in the 85 home recipes. The low leavening bread was rated good, but that with high leavening was not more than fair in quality. It was dark grayish yellow in color, and most judges objected to the flavor.

The standardized recipes for grits and mush were modified by prolonging the cooking in a double boiler 4½ and 5½ hours for mush, and 5 and 7 hours for grits, after the initial boiling for 30 minutes. This modification was suggested by the long cooking practiced in some homes and institutions.

Source of Food Materials

All corn meal and grits were obtained from milling establishments in the State as non-enriched products, partially or completely degermed. The white corn meal was obtained in 100-pound bags, the yellow in 50-pound bags and the grits in a 25-pound lot. Half of each lot was enriched with a specially prepared mixture obtained either from the South Carolina Agricultural Experiment Station or from Merck and Company. In this report, both mixtures are called premix.

For each cereal, the premix was used in the amount expected to bring the content of vitamins to the level of federal standards (5). The powder-like premix for the meal was first sifted with a small portion of corn meal, then with successively larger amounts until some 3 pounds of the meal had been used. This mixture was then added gradually to the remainder of the meal in an institutional-size mixer and stirred for approximately 3 hours. The graunlar premix for the grits was combined with this cereal by sifting through a hand flour sifter. The premix was first combined with about 1 cup of the grits, which was then divided into two portions. Each portion and half of the grits to be enriched were sifted together 10 times. These two lots of enriched grits were then combined by 10 siftings.

All other ingredients were bought as needed at local groceries. The sweet milk was whole, pasteurized; the buttermilk was a cultured product.

The one batch of grits served for all experiments with this cereal. There were three batches of white corn meal and one of yellow. Only white meal was used for corn breads and pone, only yellow meal for spoonbread, and both white and yellow for mush. Three lots of Clemson premix (from South Carolina Experiment Station) and one lot of Merck's (in this report called 4th premix) were used to enrich the different

batches of corn meal. The 3rd lot of Clemson premix contained one-third more riboflavin than the 1st and 2nd lots, and the thiamine was in the form of mononitrate instead of the hydrochloride. As will be seen later, differences in the vitamin contents of enriched meals were due in part to the varying amounts of vitamins in the premixes, but this variation in the premixes did not influence the other points of inquiry in this study.

Methods of Vitamin Analysis

In the first series of experiments, thiamine only was determined. The directions of Hennessy (7) for thiochrome assay in cereal products were followed, except for two modifications based on preliminary findings as well as on results reported from other laboratories (1, 12). Instead of .1 N sulphuric acid for extraction, 1 percent acetic acid was used, and the base exchange purification was omitted.

In all subsequent experiments, the three vitamins were determined on the same extract made with 1 percent sodium acetate buffer. The extraction procedure followed in general that described by Cheldelin, *et al* (4). However, instead of autoclaving, the samples in the buffer-enzyme mixture were heated for 90 minutes in a temperature-controlled water bath at 50° C., with continuous agitation by mechanical stirrers. Then digestion followed for 18 to 20 hours at 46° C. in an electric oven.

The determination of thiamine in the digested extracts was completed by Hennessy's thiochrome method. Microbiological methods, that of Snell and Strong for riboflavin, and of Snell and Wright for niacin, were employed. These methods are detailed in Methods of Vitamin Assay (14).

Determinations were made in duplicate in each replication, on meal, on the combined raw materials as ready to be cooked (whenever materials other than salt and water were combined with the meal), and on the cooked product.

Recoveries were obtained on each vitamin alone and on food samples supplemented with one chosen vitamin. Each vitamin used alone was subjected to all steps in the analysis of a food sample. For supplemented food samples, the "recovery sample" consisted of half the usual weight of the food sample plus a known weight of the vitamin equivalent approximately to the content in the half-sample of food. With the exceptions of spoonbread and corn pone, recovery determina-

tions were made for one or more vitamins in each run of determinations. Recoveries were calculated on the total sample basis.

RESULTS AND DISCUSSION

Recoveries

With the pure vitamin used as a sample, recoveries averaged for thiamine 99.8 percent, range 92-106; for riboflavin 103.6 percent, range 96-112; for niacin 100.7 percent, range 93-112. Total content of vitamins found in supplemented food samples compared with expected values were: thiamine average 97.2 percent, range 89-112; riboflavin average 101.9 percent, range 94-118; niacin average 105.9 percent, range 98-115.

Non-enriched versus Enriched Corn Meal and Grits

Vitamin Content of the Raw Cereals

Comparisons of the non-enriched and enriched cereals in the raw stage were made with the grits and with three batches of white meal and four lots of premix. Two portions of batch 2 of the meal were enriched, respectively, with the 2nd and 3rd lot of premix. Batch 3 of the meal was enriched with the 4th lot of premix. Since in some phases of this study only enriched cereals were used, there are more values for the enriched than the non-enriched in some of the comparisons. The single run of determinations of the three vitamins on non-enriched grits and of riboflavin and niacin on the enriched grits were considered sufficient. Two reasons support this decision. For both corn meal and grits, the additional amount of each vitamin in the enriched cereal as determined by analysis, was in good agreement with the increase expected by calculation based on the declared vitamin content on the premix label. The few retentions determined for cooked grits were in good agreement with the larger number for mush.

The data for the corresponding non-enriched and enriched raw meals and raw grits are shown in Table 2. The differences between non-enriched and enriched meals in average content of each vitamin is due in part to the variation in natural content as well as to the premix used. The lowest average thiamine content in the three non-enriched meals was only half as great as in the highest (1.00 vs 1.98 mcg/g). In the two non-enriched meals analyzed for riboflavin and niacin, the

lower value was about three-fourths of the higher—0.92 vs 1.17 mcg/g for riboflavin and 9.59 vs 12.58 mcg/g for niacin.

The thiamine content of the meals enriched with the 1st and 3rd lots of Clemson premix were in close agreement; with the 2nd lot of premix, the thiamine content was distinctly lower. Retentions and recoveries with this latter enriched meal were in agreement with others; niacin content with the 2nd and 3rd lots of premix were similar, while riboflavin in the same enriched meals differed only as expected because of the manufacturer's increase of riboflavin in the 3rd lot of premix. No explanation of the lower thiamine content of the meal enriched with the 2nd lot of premix has been found in the work with it. With the 4th lot of premix (Merck), the content of each of the three vitamins in the enriched meal exceeded the minimum federal standards.

Table 2. Content of thiamine, riboflavin and niacin in corresponding non-enriched and enriched corn meal and grits in the raw stage

Cereal	Thiamine			Riboflavin			Niacin		
	No. of replications	mcg/g		No. of replications	mcg/g		No. of replications	mcg/g	
		Range	Av.		Range	Av.		Range	Av.
White meal									
Batch 1 Non-enriched	4	1.82 1.64	1.73	Not determined			Not determined		
Enriched, 1st premix (Clemson)	7	2.45 2.56	2.53	Not determined			Not determined		
Batch 2 Non-enriched	6	1.96 2.01	1.98	3	1.04 1.29	1.17	3	12.27 12.81	12.58
Enriched, 2nd premix (Clemson)	17	2.21 2.57	2.34	4	2.44 2.51	2.48	6	32.31 33.28	32.90
3rd premix[1] (Clemson)	11	2.37 2.86	2.60	6	3.26 2.81	3.60	6	32.74 37.29	34.88
Batch 3 Non-enriched	3	.96 1.06	1.00	3	.86 .96	.92	3	9.25 10.13	9.59
Enriched, 4th premix (Merck)	3	4.53 4.65	4.59	3	3.28 3.58	3.42	3	40.80 44.96	42.40
Grits									
Non-enriched	1		.40	1		.66	1		5.63
Enriched (Clemson)	7	2.54 6.38	3.89	1		3.26	1		40.93
Minimum federal standards:			4.41			2.65			35.27

[1]The 3rd premix contained one-third more riboflavin than the 1st and 2nd, and the thiamine was in the form of mononitrate instead of the hydrochloride.

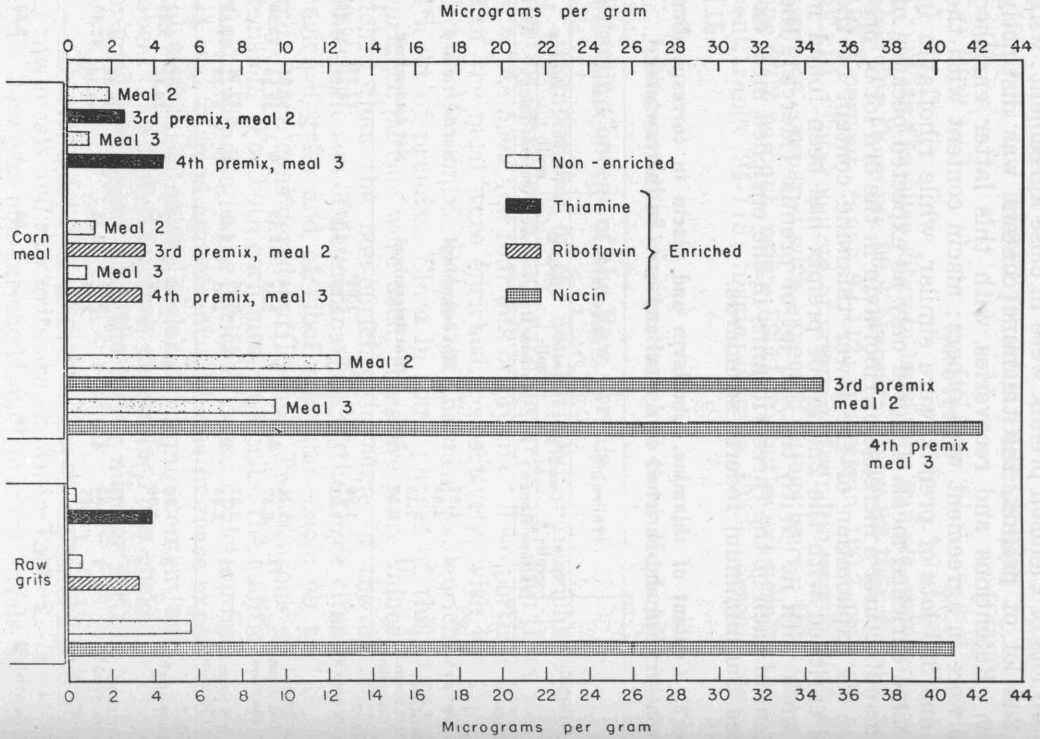

Figure 1. Content of thiamine, riboflavin and niacin in non-enriched and enriched corn meal and raw grits.

Apparently more of the vitamin-bearing portion of the corn grain is removed in the making of grits than of meal (Table 2). Especially is this true of the thiamine, which was so low in non-enriched grits that it is considered a trace only. The riboflavin and niacin contents of non-enriched grits were found to be from one-half to two-thirds as much as in the non-enriched meals. Hence the need of enrichment is greater for grits than for corn meal.

The single replication for determination of riboflavin and niacin in the enriched grits shows that minimum federal standards for these vitamins were exceeded. The much wider range of thiamine values found for the enriched grits than for the meals is thought to be due mainly to the granular nature of the grits which precluded obtaining homogeneous samples, and the relatively small size of samples. Wide variation occurred between duplicate and triplicate 5-gram samples as well as between samples on different days. Without knowledge of the manner in which the thiamine was incorporated into the premix, the speculation is ventured that thiamine may have been less uniformly distributed in the premix than the riboflavin and niacin. This suggestion appears to have support in the narrow range of thiamine values in the boiled grits—from 0.60 to 0.67 mcg/g for four replications in 3 days.

The graphic presentation of the vitamin content of non-enriched and enriched raw cereals (Figure 1) permits comparison of the effect of using the Merck premix and the 3rd lot of Clemson premix to enrich corn meal. In these two enriched meals, riboflavin contents were similar. Merck-enriched meal was higher in niacin by 21 percent and in thiamine by 77 percent than the meal to which the 3rd lot of Clemson premix was added. The graphs emphasize the far greater content of niacin than of the other two vitamins in both enriched corn meal and grits. Those who originally determined the proportions of vitamins in the premixes aimed at an abundance of niacin as a measure to combat pellagra among population groups eating large amounts of corn meal and grits.[2] However, enrichment of meal with Merck premix effected comparable increases in thiamine (4.7 x non-enriched) and niacin (4.3 x non-enriched). The riboflavin of enriched meal was 3.7 times that of the non-enriched. Enrichment (Clemson) of grits made its content per gram of niacin and of riboflavin approximately the same as in enriched (Merck) corn

[2]Private communication from Dr. E. J. Lease, South Carolina Agricultural Experiment Station, Clemson, S. C.

meal; but when grits were not enriched, they were practically devoid of thiamine.

Vitamin Content of Corn Bread and Grits

The food preparations chosen to compare non-enriched and enriched corn meal and grits after cooking were corn bread, made by the standard sour milk recipe, and short cooked grits. After removing samples from some batches, the remainder of the boiled grits was poured into No. 2 tin cans to cool. The cold mold of grits was removed from the can and slices 5/8-inch thick cut off to fry. Frying was done in a No. 6 iron skillet with just enough fat to keep the grits from sticking. Only two batches of non-enriched meal and the corresponding enriched meals (different Clemson premixes) were employed for this phase of the study.

Table 3 shows that the benefits of enrichment carry over into the cooked preparations. As with the raw enriched cereals, niacin content was much higher in the corn bread and cooked grits than were thiamine and riboflavin (Figure 2). The relatively greater increase of niacin content of the en-

Table 3. Content of thiamine, riboflavin and niacin in corresponding non-enriched and enriched corn bread and cooked grits

Food prepration	Thiamine			Riboflavin			Niacin		
	No. of replications	mcg/g Range	mcg/g Av.	No. of replications	mcg/g Range	mcg/g Av.	No. of replications	mcg/g Range	mcg/g Av.
Corn bread									
White meal									
Batch 1									
Non-enriched	3	.91 .99	.94	Not determined			Not determined		
Enriched, 1st premix (Clemson)	4	1.17 1.25	1.21	Not determined			Not determined		
Batch 2									
Non-enriched	3	.92 1.00	.97	3	1.52 1.81	1.63	3	4.81 5.66	5.21
Enriched, 2nd premix (Clemson)	3	1.12 1.12	1.12	3	2.00 2.27	2.12	3	13.29 14.65	13.97
Grits									
Boiled 30 min.									
Non-enriched	1		.03 =trace	1		.11	1		.92
Enriched (Clemson)	4	.60 .67	.63	1		.61	1		6.89
Fried after boiling 30 min.									
Non-enriched	1		.06 =trace	1		.16	1		1.48
Enriched (Clemson)	2	.80 .89	.84	1		.83	1		10.22

riched cooked foods is explained in part by the greater abundance of niacin in the premix, and in part by variation in the stability of the vitamins. Niacin and riboflavin are least and similarly affected by the cooking processes, and thiamine most.

In comparison with the raw cereals, the corn bread and cooked grits contained much less of each of the vitamins per gram, except that the difference was less marked for riboflavin in corn bread. Compare Figures 1 and 2. The lower content of vitamins in the cooked foods is due largely to the higher water content. However, in corn bread, the eggs and milk increase the vitamin content, especially riboflavin. Thus,

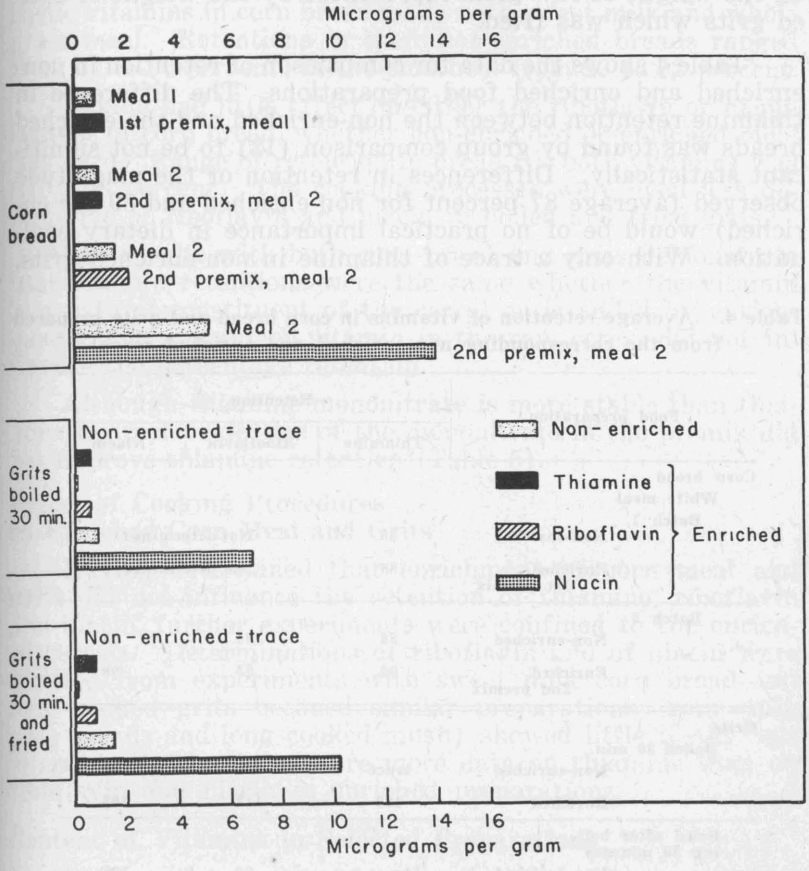

Figure 2. Content of thiamine, riboflavin and niacin in non-enriched and enriched corn bread and cooked grits.

even the non-enriched corn bread is a better food than the vitamin content of the meal would suggest. In the high quality proteins of milk and eggs is another advantage of combining them with enriched cereals.

Retention of Vitamins in Corn Bread and Grits

Retention of each vitamin was calculated on the total batch moist basis. Because of the great variation in thiamine content between individual samples of raw enriched grits, the average mcg/g of all samples of them was used with the value for each batch of cooked grits to calculate retention of this vitamin. For fried grits, retention was based on the weight of raw grits represented by the weight of boiled grits which was fried.

Table 4 shows the data for comparison of retention in non-enriched and enriched food preparations. The difference in thiamine retention between the non-enriched and the enriched breads was found by group comparison (13) to be not significant statistically. Differences in retention of the magnitude observed (average 87 percent for non-enriched and 89 for enriched) would be of no practical importance in dietary evaluation. With only a trace of thiamine in non-enriched grits,

Table 4. Average retention of vitamins in corn bread and grits prepared from the corresponding non-enriched and enriched cereal

Food preparation	Retention, %		
	Thiamine	Riboflavin	Niacin
Corn bread			
White meal			
Batch 1			
Non-enriched	88	Not determined	
Enriched, 1st premix	89	Not determined	
Batch 2			
Non-enriched	86	96	95
Enriched, 2nd premix	90	93	98
Grits			
Boiled 30 min.			
Non-enriched	trace	104	100
Enriched	102	113	103
Fried after boiling 30 minutes			
Non-enriched	trace	96	105
Enriched	92	106	104

no calculation of retention can be made. Thiamine in enriched grits boiled 30 minutes was not affected by the cooking, but the same grits after frying showed a slight loss of the vitamin (92 percent retention). The higher thiamine content per gram in the fried grits is due to loss of water during frying.

Reports have been found from only two other laboratories on thiamine in corn meal and grits in cooked form. At the South Carolina Station (9), cooked enriched grits contained only 9 percent less thiamine than the raw, 5 percent having been lost by washing the raw grits and 4 percent by cooking 1 hour in a double boiler. Hoffmann-LaRoche Laboratories (3) found similar retentions for natural occurring and synthetic vitamins in corn bread made with sweet milk and whole grain meal. Retentions in their non-enriched breads ranged from 91 to 96 percent; in the enriched, from 89 to 92 percent.

Baking had little effect on either the riboflavin or niacin content of corn bread, whether non-enriched or enriched meal was used. Range of retention in bread for both vitamins was 93 to 98 percent. The cooking processes were even less destructive of riboflavin and niacin in boiled and fried grits.

The results with both corn bread and grits demonstrate that vitamin retentions were the same whether the vitamin is a natural constituent of the cereal or is added by enrichment. The amount of vitamin in the raw cereal did not influence the percentage retention.

Although thiamine mononitrate is more stable than thiamine hydrochloride, use of the mononitrate in the premix did not improve thiamine retention (Table 5).

Effect of Cooking Procedures on Enriched Corn Meal and Grits

Having determined that enrichment of corn meal and grits did not influence the retention of thiamine, riboflavin and niacin, further experiments were confined to the enriched cereals. Determinations of riboflavin and of niacin were omitted from experiments with sweet milk corn bread and long cooked grits because similar preparations (sour milk corn breads and long cooked mush) showed little if any loss in cooking. Thus, there are more data on thiamine than on riboflavin and niacin in enriched preparations.

Content of Vitamins in Selected Preparations

Data on the content of each vitamin and the range and average in micrograms per gram for each kind of preparation,

Table 5. Retention of thiamine hydrochloride and of thiamine mononitrate in corn meal mush and corn bread

Preparation	No. of replications	Retention, %			
		Thiamine hydrochloride		Thiamine mononitrate	
		Range	Average	Range	Average
Mush					
White meal boiled 30 min.	2	98.9 102.8	100.9		
	3			96.1 106.2	100.1
Corn bread					
2nd premix white meal	6	88.5 92.2	89.6		
3rd premix white meal 2 yellow meal 2	4			81.5 89.2	85.7
5th premix[1] yellow meal	2			83.0 86.7	84.9

[1]These corn breads were in another study.

along with the number of replications in each case, are shown in Table 6. Three types of corn breads (Clemson premix)—sour milk, sweet milk and low leavening—showed a similar content of thiamine, riboflavin and niacin. But in high-leavening corn bread, only the niacin was in agreement with the other Clemson premix breads. The riboflavin was slightly lower and the thiamine amounted to merely a trace, less than one-twelfth as much as in the other three breads. The sour milk and sweet milk standard corn breads made with meal carrying Merck premix were in close agreement for each vitamin. But the content of each vitamin was higher in the Merck premix breads than in those made with meals enriched with Clemson premix. The Merck-enriched breads had about one-fourth more riboflavin and niacin per gram than the Clemson premix breads, and approximately two-thirds more thiamine. This is strong evidence that, other things being equal, the more of these B vitamins in the raw stage, the more also after cooking.

Of the other ready-to-eat preparations, pone most nearly approached the good corn breads in vitamin content, with riboflavin slightly less, thiamine slightly more and niacin about one-half more than in the corn breads. Spoonbread, short cooked mush and short cooked grits were fairly similar to each other with respect to each vitamin. Their content of

each vitamin was roughly one-third to one-half that in the corn breads, with one exception — the riboflavin content of spoonbread, on account of the milk and eggs in it, were similar to the higher riboflavin content of the corn breads. Long cooked grits and mush had less thiamine than the short cooked. The higher per gram content of each vitamin in fried than in boiled grits was due to loss of water during cooking. The actual loss of thiamine caused by frying showed up in the lower total content per batch of fried than of the corresponding boiled grits.

A comparison was made of yellow and white corn meal mush. These particular batches of meal were enriched with the same proportion of Clemson premix (3rd lot), and all details in the cooking processes were the same for the two meals. Short cooked mush was kept bubbling over direct heat from a gas burner. The constant temperature reached at 10 to 15 minutes after bubbling began was 94-95° C. Constant temperature level while cooking in the double boiler was 83-84° C.

Mushes of the two colors had similar content of riboflavin and of niacin. Table 6 shows that this white mush had a higher thiamine content per gram than the yellow. However, two other batches of yellow meal were used later in another study. One of these was found to be as high in thiamine as the white meal in this study, the other had more thiamine.

The foregoing comments upon the content of the vitamins on a per gram basis in corn meal and grits after cooking do not constitute a dietary evaluation of the several preparations. The data in Table 6 are essentially for the calculation of retention and, along with the designated size of servings, they have been used for estimation of vitamin contribution when a given preparation is eaten in normal amounts.

Retention of Vitamins in Selected Preparations

Retentions were calculated on the total batch moist basis. Table 7 gives the retention data along with the pH values before cooking for corn bread, pone and spoonbread, and after cooking for mush and grits.

The data in Table 7 indicate that pH of batter has a bearing on retention of thiamine in corn bread. With pH values between 5.4 and 6.2, inclusive, average retentions for sour

milk standard corn bread were 89 and 85 percent, for low leavening 89 percent, and for sweet milk breads 84 and 85 percent, all comparable values. However, in high leavening bread, with pH 6.6 and 6.7, retention was only 7 percent. Evidently, between pH of 5.4 and 6.6, there is a critical value at which thiamine in corn bread is rapidly destroyed in the baking process. This point is under investigation.

Table 6. Content of vitamins in enriched corn meal and grits preparations

Food preparation[1]	Thiamine			Riboflavin			Niacin		
	No. of replications	mcg/g		No. of replications	mcg/g		No. of replications	mcg/g	
		Range	Av.		Range	Av.		Range	Av.
Corn bread									
Sour milk standard	7	1.12 1.25	1.17	3	2.00 2.27	2.12	3	13.29 14.65	13.97
Sweet milk standard	4	1.07 1.20	1.13		Not determined				
Sour milk low leavening	3	1.13 1.19	1.17	2	1.86 1.97	1.92	3	13.05 13.76	13.49
Sour milk standard Merck premix[2]	4	1.91 1.96	1.94	1		2.51	1		16.93
Sweet milk standard Merck premix[2]	5	1.79 1.97	1.92	2	2.66 2.73	2.69	2	16.64 17.68	17.16
Sour milk high leavening	3	.09 .10	.09 =trace	3	1.58 1.92	1.72	3	13.50 14.98	14.12
Pone	6	1.63 1.70	1.67	2	1.46 1.85	1.71	6	22.32 24.13	23.28
Spoonbread	5	.52 .66	.59	3	2.11 2.24	2.18	3	6.41 6.69	6.57
Mush									
Short cooked white meal	7	.43 .48	.44	3	.61 .69	.65	3	5.75 5.95	5.87
yellow meal	6	.23 .28	.25	1		.58	1		5.23
Long cooked white meal	4	.33 .38	.35	3	.59 .70	.63	3	5.93 6.92	6.32
yellow meal	2	.17 .17	.17	1		.49	1		5.09
Grits									
Short cooked	4	.60 .67	.63	1		.61	1		6.89
Long cooked	4	.48 .60	.55		Not determined				
Fried from short cooked	2	.80 .88	.84	1		.83	1		10.22
Fried from long cooked	4	.62 .79	.71		Not determined				

[1]White meal for all except spoonbread, and mush as indicated.

[2]All other preparations enriched with Clemson premix.

Table 7. Retention of vitamins in enriched corn meal and grits preparations

Food preparation[1]	pH	Retention, %					
		Thiamine		Riboflavin		Niacin	
		Range	Av.	Range	Av.	Range	Av.
Corn bread	**Before cooking**						
Sour milk standard	5.4 to 6.0 Av., 5.8	87 92	89	90 98	93	96 100	98
Sweet milk standard	6.1 & 6.2	82 87	84	Not determined			
Sour milk low leavening	5.4 & 5.5	86 90	89	92 99	96	98 98	98
Sour milk standard Merck premix[2]	5.8 & 5.9 Av., 5.9	83 87	85	1 replication only	98	1 replication only	95
Sweet milk standard Merck premix[2]	6.0 & 6.05 Av., 6.01	82 89	85	107 98	102	93 98	95
Sour milk high leavening	6.6 & 6.7	7 7	7	82 93	89	104 115	108
Pone	6.0 & 6.2	86 96	91	92 103	98	93 102	98
Spoonbread	6.5 & 6.7	84 96	89	85 97	91	98 104	101
Mush	**After cooking**						
Short cooked white meal	6.2 & 6.4	95 106	100	104 117	109	100 105	102
yellow meal	6.6 & 6.7	91 104	100	1 replication only	120	1 replication only	112
Long cooked white meal	6.5	72 81	76	98 106	103	100 115	107
yellow meal	6.8 & 6.9	66 68	67	1 replication only	108	1 replication only	112
Grits							
Short cooked	6.65	96 105	102	1 replication only	113	1 replication only	103
Long cooked	6.65	62 80	74	Not determined			
Fried[3] from short cooked	6.65	90 94	92	1 replication only	106	1 replication only	104
Fried from long cooked	6.65	57 72	67	Not determined			

[1]White meal for all except spoonbread, and mush as indicated.

[2]All other preparations enriched with Clemson premix.

[3]Calculation of retention in fried grits was based on raw grits represented by amount of boiled grits used to fry.

A variance analysis was made of the thiamine retentions by the five groups of corn breads which contained from 84 to 89 percent of the content of this vitamin in the corresponding batters. The variation within the groups was greater than between the groups, the respective mean squares being 19.98 and 5.96.

Thiamine contents of other corn meal preparations indicate that pH is not the only factor influencing retention. Pone retained from 86 to 96 percent of the thiamine in the uncooked mixture. The pH values were 6.0 and 6.2, which are within the safe range for corn breads. In contrast, spoonbread with the same pH as for high leavening corn bread (6.5 and 6.7), retained in the cooked product 89 percent, or as much as the best average retention in good corn breads. Also both mush and grits with pH ranging from 6.2 to 6.7, showed complete retention after 30 minutes boiling. It is hoped that the studies in progress will throw light on these results.

Other conditions being the same, prolonging the cooking time lowered the thiamine retention. Grits cooked in a double boiler 5 and 7 hours, after having boiled 30 minutes, contained only two-thirds of the thiamine in the raw cereal. Long cooked yellow mush (4½ and 5½ hours in a double boiler after 30 minute boiling) contained two-thirds and white mush three-fourths as much thiamine as the corresponding meal. It is questionable whether the difference noted in retentions of these yellow and white mushes represents a characteristic difference. There were too few replications for yellow mush for statistical analysis. It does not seem justifiable to attribute this difference between white and yellow mush to the color of the meal as this difference is slightly less than the variation within the four replications of white mush and between highest and lowest retentions for pone, spoonbread and boiled grits.

Recooking, as in frying of grits, lowered the thiamine content—from 102 percent in grits boiled 30 minutes to 92 percent after subsequent frying, and in long cooked grits from 74 to 67 percent. Retention in fried grits was based on content of the raw grits represented by the amount of boiled grits used to fry.

The data for riboflavin and niacin are interpreted to mean that in all preparations the cooking process has little or no effect on the retention of these two vitamins (Table 7).

Comparison with Other Studies

Vitamin retentions found in this study for corn meal and grits preparations agree with those reported by other work-

ers for other whole grain and enriched cereals. In all studies, retentions were calculated on the moist (not dried) basis.

Aughey and Daniel (2) found complete retention of thiamine in rolled oats and cracked wheat boiled 2 minutes, plus double boiler cooking of the oats for 2 hours and of the wheat for 30 minutes. The wheat ground into flour and made into water bread retained 86 percent of the thiamine.

Munsell, *et al,* (11) enriched farina by the addition of wheat germ and of two different mixtures of vitamins and minerals. After cooking for 5 minutes directly over an elecric burner, retentions for the three ways of enriching ranged from 92.7 to 101.0 percent for thiamine, 83.6 to 109.7 percent for riboflavin and 86 to 102.3 percent for niacin.

Lincoln, *et al,* (10) determined retention of thiamine in quick-cooking farina, cracked wheat, oatmeal and enriched farina after cooking in flowing steam at 100 to 101° C. for intervals of 5, 15, 30, 60 and 120 minutes. After cooking for 5 minutes, thiamine was lowered only in cracked wheat, to 95.7 percent. After 15 minutes, retentions ranged from 87.0 to 97.8 percent. With still longer cooking, retentions were progressively less and were related to pH values. After 120 minutes cooking, quick cooking farina retained 59 percent (pH 6.85) ; cracked wheat, 73 percent (pH 6.30) ; oatmeal, 80 percent (pH 6.20) ; and enriched farina 85 percent (pH 5.80). The two lowest pH values are in the same range as those favorable to retention of 82 to 92 percent in the standard recipe corn breads in this study. Loss of thiamine after 15 minutes cooking of cereals by Lincoln, *et al,* may be due to the higher temperature than that used for mush and grits.

The Texas study, and those cited, show that short cooking of breakfast cereals does not affect the amount of thiamine, riboflacin and niacin. Whatever may be added by enrichment means just that much improvement in dietary value if the cereal is cooked 30 minutes or less in a utensil over direct heat.

The findings on retention of the three vitamins in corn meal and grits preparations indicate that there need be concern only for the preservation of thiamine in ordinary cooking procedures. Measures favorable to thiamine retention in attractive and palatable products include a cooking period no longer than necessary to obtain a high quality product and, with corn bread, to keep the pH of the batter below 6.2. This will be done if no more than 4.5g (1½ teaspoons) of baking powder to 2 cups of cereal (meal plus flour) and no more than

1.9g (½ teaspoon) soda to 1½ cups sour milk are used in making the corn bread. These proportions were exceeded for baking powder in 46 out of 75 recipes collected from Texas homes, and for soda in 32 out of 74 recipes. The high leavening proportions used in this study were exceeded in 27 home recipes. Hence, with nearly half of the recipes, an unduly great destruction of thiamine would be expected, and with approximately one-third of them the benefits of thiamine enrichment would probably be nullified.

Those who make corn bread need to learn how to combine palatability and attractiveness with the best retention of thiamine obtainable. Short cooked mush and grits, with complete retention of all three of the B vitamins, are very palatable, attractive products. They are stiff enough when cold to slice for frying. If the diet is low in thiamine, it would be better to serve mush and grits after only 30 minutes boiling, rather than as a fried product.

Dietary Contributions

The dietary contribution of the corn meal and grits preparations was estimated by comparing the content of each vitamin in one serving of the food with the amounts recommended by the Food and Nutrition Board of the National Research Council (6) as a desirable daily intake for a physically active man and for a moderately active woman.

The spoonbread recipe provided six servings; all others four servings, except pone. The pone recipe was for two servings, as a matter of convenience, without sacrificing either laboratory requirements or similarity to home procedure. The servings were moderate to generous in size. Most of the judges agreed with the authors that the designated servings are representative of actual practice, especially in families where corn meal and grits preparations are eaten frequently.

The calculated dietary contributions are shown in Table 8. For the enriched corn bread, only those from the Merck enriched meals were used. For pone, mush and spoonbread, the average values of each preparation made with meals enriched with Clemson premix were converted to the values expected if the meal had been enriched with Merck premix.

The higher proportion of the recommended allowances for a woman than for a man supplied by each food preparation is due to the smaller allowances for a woman, but the same size of servings as for a man.

One serving of the enriched corn bread furnishes approximately one-fifth of a man's and one-fourth of a woman's allowance of thiamine and riboflavin, and approximately one-sixth of a man's and one-fifth of a woman's allowances of niacin. In relation to allowances, there is no greater abundance of niacin than of thiamine and riboflavin in the corn bread, as is true of the absolute content per gram of both bread and corn meal. Enriched corn bread contributes about 2 times as much thiamine, about 1½ times as much riboflavin and 3 times as much niacin as the non-enriched.

Only two-thirds as much enriched pone by weight as of enriched corn bread is needed to supply approximately the

Table 8. Dietary contributions from one serving of corn meal and grits preparations in comparison with recommended daily allowances[1]

Food preparation		Grams per serving[3]	Percentage of allowance[2]					
			For physically active man			For moderately active woman		
			Thiamine	Riboflavin	Niacin	Thiamine	Riboflavin	Niacin
Corn bread								
Sour milk standard	Non-enriched	148	9	13	5	12	16	6
Sour milk standard (Merck premix)	Enriched	148	19	21	17	24	25	21
Sweet milk standard (Merck premix)	Enriched	148	19	22	17	24	26	21
Pone	Enriched	95	17	12	17	22	14	22
Spoonbread	Enriched	100	10	16	8	12	20	9
Mush								
Short cooked	Enriched	190	10	6	9	12	7	11
Long cooked	Enriched	185	7	6	9	9	7	11
Grits								
Short cooked	Non-enriched	172	none	1.1	1.1	none	1.3	1.3
Short cooked	Enriched	172	7.3	5.8	7.9	9.1	6.9	9.9
Long cooked	Enriched	144	5.3	Not determined		6.6	Not determined	
Fried from short cooked	Non-enriched	115	none	1.0	1.1	none	1.2	1.4
Fried from short cooked	Enriched	115	6.5	5.3	7.8	8.1	6.4	9.8
Fried from long cooked	Enriched	101	4.7	Not determined		5.9	Not determined	
[1]Recommended mg per day:			1.5	1.8	15	1.2	1.5	12

[2]Nearest whole number except for grits where one decimal place used to show effect of cooking.

[3]One serving is ½ batch of pone; 1/6 of spoonbread; ¼ of each other preparation.

same proportion of the allowances for thiamine and niacin. But for riboflavin, the enriched pone is of about the same value as the non-enriched bread. This would be true even though the same weight of pone and corn bread were eaten. The reason is that the milk and egg in corn bread supply relatively more riboflavin than of thiamine and niacin.

Enriched spoonbread and short cooked mush per serving supply about half as much of thiamine and niacin as does enriched bread. This is due chiefly to the greater water content in spoonbread and mush. For the same reason, the contribution of riboflavin from mush is about one-third of that from enriched bread; but spoonbread with eggs and milk in it would provide four-fifths as much riboflavin as the bread.

Long cooked enriched mush and short cooked enriched grits are similar in the proportion of the allowance of thia-

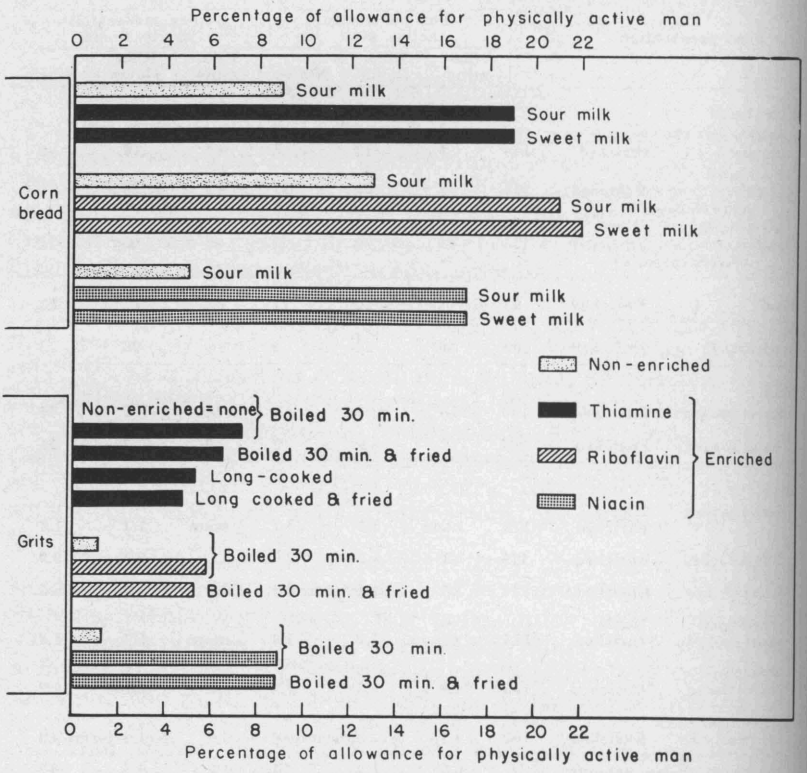

Figure 3. Percentage of allowances of thiamine, riboflavin and niacin for a physically active man from one serving of non-enriched and of enriched corn bread and cooked grits.

mine, riboflavin and niacin that they supply—from 6 to 9 percent for a man and from 7 to 11 percent for a woman.

Contributions from enriched long cooked and from fried grits are the smallest of any enriched preparation, only 5 and 6 percent of a man's allowance for thiamine and riboflavin and 6 to 8 percent for a woman's. Niacin contribution is a little better, 8 percent for a man, 10 percent for a woman. The servings of enriched short cooked, long cooked and fried grits represent the same weight of raw grits; therefore, the method of cooking and not the size of serving accounts for the small differences in contributions.

Non-enriched grits, no matter how cooked, were so low in all vitamins as to be negligible from a dietary standpoint. Enrichment of grits changed "no value" to "fair value."

Figure 3 aids in comparing the percentage of daily recommended allowances supplied by non-enriched and enriched corn bread and cooked grits. This figure and the data in Table 8 emphasize that a goodly content of each vitamin in the raw cereal is a primary essential, although other factors have an influence on the vitamin value of the ready-to-eat preparation. The other factors include the amount of cereal used in the preparation; the addition of vitamins in other ingredients, as by egg and milk in corn bread and spoonbread; the amount of water in the cooked food; the percentage retention of the vitamins and the amount of the food eaten.

Compared with recommended allowances, enriched corn bread is an excellent source of all three vitamins. Even if the generous serving were reduced to half that size, enriched corn bread would be a good source of thiamine, riboflavin and niacin. Enriched pone is an excellent source of thiamine and niacin, and good for riboflavin. Enriched spoonbread and short cooked mush are good sources of thiamine and niacin; but for riboflavin, spoonbread is excellent, mush only fair. Grits, per serving of the designated size, even when enriched, can be rated only a fair source of the three vitamins, except good in niacin for a woman. If, as is frequently done, two or more servings of one or more of such enriched corn meal and grits preparations are eaten daily, they would supply a highly important part of the recommended allowances.

SUMMARY AND CONCLUSIONS

This study was made to determine the extent to which the increase in vitamin content due to enriching corn meal and grits improves the vitamin value of the cereals when prepared for eating.

The corn meal and grits were obtained from Texas mills as non-enriched degermed products. A portion of each batch was enriched in the laboratory with a commercial enriching mixture. Corn bread, corn pone, spoonbread, mush, boiled grits and fried grits each made by a standardized recipe with enriched cereal or the corresponding non-enriched, were analyzed for thiamine, riboflavin and niacin. Retention of each vitamin in each preparation was calculated on the total batch fresh basis.

Enriched corn meal, with vitamin content a little above minimum federal standards, contained 4.7 times as much thiamine, 3.7 times as much riboflavin and 4.3 times as much niacin as the corresponding non-enriched meal. Without enrichment, grits were practically devoid of thiamine. Enriched grits had 5.0 times as much riboflavin and 7.0 times as much niacin as the non-enriched. Corn meal and grits after enriching were comparable in their vitamin contents.

The increase in vitamin content due to enrichment made no difference in the percentage retention of any of the vitamins. Results were similar with yellow and white meal. None of the cooking processes changed the content of riboflavin and niacin.

There was complete retention of thiamine in mush and grits boiled 30 minutes; but after further cooking 4 to 7 hours in a double boiler, only two-thirds to three-fourths of the thiamine remained. Frying of cold boiled grits reduced the thiamine content, but to a less extent than did prolonged cooking in a double boiler. Thiamine retention in corn bread was related to pH of the batter. With pH from 5.4 to 6.2 for sour milk, sweet milk and low leavening corn breads, thiamine retentions ranged from 84 to 89 percent. But corn bread made with excessive leavening (pH of batter 6.6 and 6.7) retained only 7 percent of the thiamine. In pone, spoonbread and short cooked mush and grits, high thiamine retention (89 to 100 percent) was associated with a range of pH values as wide as those accompanied by both the good and the very low retentions in corn breads.

Compared with recommended daily allowances, enriched corn bread is an *excellent* source of all three B vitamins, as is pone for thiamine and niacin, and spoonbread for riboflavin. One serving of enriched corn bread (148 g) furnishes approximately one-fifth of a man's and one-fourth of a woman's allowance of thiamine and riboflavin, and approximately one-sixth of a man's and one-fifth of a woman's allowance of niacin. One serving of enriched pone (95 g) is similar to enriched corn bread in its contribution of thiamine and niacin,

but for riboflavin it is only half as good. The milk and eggs used in corn bread and spoonbread raise the content of each vitamin, especially riboflavin, and by their high quality proteins further increase the food value of these cereal preparations, making them the better to combat pellagra and promote general good health.

Spoonbread and short cooked mush, which contain more water than corn bread and pone, make a *good* contribution of thiamine and niacin—in one serving about one-tenth of the allowance. Short cooked mush is only *fair* for riboflavin. A single serving of enriched long cooked mush, and of short cooked, long cooked or fried grits, makes only *fair* contributions to the allowances of each vitamin.

When, as is frequently done, two or more servings of enriched corn meal and grits preparations are eaten daily, their importance in making up a good diet will be the greater. However, cooking methods must be used that ensure the best retention of thiamine.

Owing to the popularity in Texas of corn meal and grits dishes, it is highly desirable to have only the enriched cereals available. As with enrichment of flour and oleomargarine, Texas might well join other Southern States in having a law requiring enrichment of corn meal and grits.

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